STAFF SUMMARY SHEET

	TO	ACTION	SIGNATURE (Surname), GRADE AND DATE		TO	ACTION	SIGNATURE (Surname), GRADE AND DATE
1	USAFA/ DFCE	Coord	for Dr Henry Lt Col Sullivan x9119	6			
2	USAFA/ DFER	Sign	Soltz, AD-25, 23 Jan 15	7			
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SUMMARY

1. PURPOSE. To provide security and policy review on the document at Tab 1 prior to release to the public.

2. BACKGROUND.
Authors: Karen Henry, Heidi Hunter, Ben Fonte

Title: THE INFLUENCE OF PROCESSING SOIL WITH A COFFEE GRINDER ON SOIL CLASSIFICATION

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Other:_journal technical note (shorter than an article)

Description: For submission for consideration for publication in the ASTM Journal of Geotechnical TEsting

3. DISCUSSION. N/A

4. VIEWS OF OTHERS. N/A

5. RECOMMENDATION. Approve document for public release. Suitability is based solely on the document being unclassified not jeopardizing DoD interests, and accurately protraying official policy.

Karen S. Henry
Professor/DFCE

1 Tab

AF IMT 1768, 19840901, V5 PREVIOUS EDITION WILL BE USED.

TECHNICAL NOTE

Karen S. Henry, PhD, PE[1], *TSgt Heidi Hunter*[2] *and Benjamin Fonte*[3]

THE INFLUENCE OF PROCESSING SOIL WITH A COFFEE GRINDER ON SOIL CLASSIFICATION

Abstract

Use of a coffee grinder to break up clods of soils is one of the recommended practices of the Rapid Soils Analysis Kit (RSAK). This leads to the question that it may produce fines by cutting/breaking larger particles—potentially leading to the mis-classification of soil. In order to investigate this hypothesis, we performed a laboratory investigation to determine if the use of a coffee grinder produces fines from sand-size particles and whether the production of more fines can result in a different USCS classification by some combination of adding soil fines and changing the Atterberg Limits of the fines tested. Three soils were tested—Ottawa Sand (SP), a poorly graded sand with silt (SP-SM) and a sandy lean clay (CL). Processing the soils for 90 seconds in a coffee grinder produced from 15.9% to 18.5% fines from the Ottawa Sand and established that the coffee grinder breaks down sand particles into fines. For the coarse Elevator Soil, originally an SP-SM, the fines production changed the soil classification to SM, while the Liquid Limit decreased from a measureable 21 to non-plastic, and Plastic Limit decreased from 19 to 17. For the Harte Clay (CL), the soil classification did not change; but the Liquid Limit and Plastic Limit both significantly increased. Therefore, for both the production of fines and the resulting impact on Atterberg Limits, the influence of using a coffee grinder to process soil cannot be quantified without further, systematic study.

1. Introduction

The Rapid Soils Analysis Kit (RSAK) was recently developed by the US Army Corps of Engineers under the Joint Rapid Airfield Construction program (JRAC), to address the need for rapid, on-site soil characterization (Berney and Wahls, 2008). The RSAK provides soil

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classification and construction design parameters (e.g., California Bearing Ratio values) within a few hours, requires little experience on the part of the operators and can be used in place of the field soil classification techniques such as those described in the former Army Technical Manual TM 5-410 (republished as TM 3-34.64) in which several tests requiring skilled technicians are used (ribbon test, jar test, etc..) (Berney and Wahls, 2008). It includes a small field laboratory consisting of a microwave, electric balance, sieve shaker, sieves, coffee grinder, plastic limit tool, bowls, spatulas, and scoops. To classify soils, a dry sieve analysis is performed, as is a Plastic Limit (PL) test. The grain size distribution information and the PL (which utilizes linear regression to predict the Plasticity Index, or PI) is then used to classify the soil and predict Proctor compaction curves and soaked California Bearing Ratio (CBR) values as a function of dry unit weight.

The RSAK recommends the use of a small, hand-held coffee grinder to process fine-grained soils (i.e., break down fines that have clumped), described as follows (Berney and Wahls, 2008):

> After microwave drying of soils containing a fine-grained fraction, "clods" of soil will be present as a result of rapidly driving out moisture from wet clumps of soil. Left alone, these clods would skew the grain size curve to the coarse side and create a false classification of the soil, which in turn would lead to improper construction guidance. Traditional tools to process soils are the mortar and pestle, which can be used to grind down hard clods into much finer material. The mortar and pestle also allows separation of true aggregate from soil clods by observing their response to grinding. Once a coarse separation of the soil has occurred and any aggregate has been removed, there will still remain a large number of very fine clods that cannot be ground any finer with the mortar and pestle. To reduce these fine clods to a powdered material that can pass the No. 200 sieve during dry sieving, the RSAK introduces a coffee grinder that can pulverize these fine clods into powder. As shown in the classification section of the report, the coffee grinder makes classification of fat and lean clays much more feasible, whereas mortar and pestle refinement typically results in a sandy-clay designation.

The suggested use of a coffee grinder leads to the question that it may produce fines by cutting/breaking larger particles—potentially leading to the mis-classification of soil. In early work, the US Army noted the importance of using the mortar and pestle properly to break down clods of fine-grained soil (TM 3-34.64, Chapter 5 regarding field classification of soil):

> A rubber-faced or wooden pestle and a mixing bowl is recommended for pulverizing. Lumps may also be pulverized by placing a portion of the sample on a firm, smooth surface and using the foot to mash it. If an iron pestle is used for pulverizing, it will break up the mineral grains and change the character of the soil; therefore, using an iron pestle is discouraged.

As noted, the use of the hard pestle is purported to break soil particles. We hypothesized that use of a coffee grinder (with steel blades) to process soil changes the grain size distribution due to cutting and/or breaking of particles. Furthermore, this addition of fines can change the Atterberg Limits in at least some cases. In order to investigate this hypothesis, we performed a laboratory investigation to determine if the use of a coffee grinder produces fines from sand-size particles and whether the production of more fines can result in a different USCS classification by some combination of adding soil fines and changing the Atterberg Limits of the fines tested. The purpose of this article is to document the results of the experimental investigation.

2. Literature review/Previous work

As noted above, early US Army guidance recommended using only a rubber-faced or wooden pestle with a mixing bowl to break up soil clods. Producing fines by improper soil processing has been a concern for a while. An early laboratory manual for use in colleges and universities notes that a disturbed soil sample is ready for testing when "all particles smaller than the 40 mesh have been separated sufficiently to pass the 40 mesh without fracturing the individual grains;" and as regards to dry soil (Dawson, 1949).

Kayabali (2011) tested the hypothesis that because the Liquid Limit and Plastic Limit are directly related to grain size (i.e., specific surface area), Atterberg Limit tests performed on the same soil would be higher for the -#200 Sieve fraction compared to the -#40 Sieve fraction that is utilized for the United Soil Classification System (USCS) of soils. He performed Atterberg Limit tests on 60 samples of lacustrine clay (collected from different locations) —each pair of tests comprised one each of the -#200 Sieve fraction and the -#40 Sieve fraction of the same soil. He found that both the Liquid Limit and the Plastic Limit were on average 10%-20% higher on the -#200 Sieve fraction. Further, in 19 of the 60 cases, the USCS Classification of the soil changed as a result of using the different fractions of soil. Hence, there is evidence that when the sampling and laboratory method used results in a fines increase, 1) the Atterberg Limits increase and 2) this sometimes changes the soil classification.

3. Experimental design

Our experiments were designed to test the hypothesis that using a coffee grinder to process dry soil produces significantly more soil fines as compared to the standard use of mortar and pestle, as prescribed by ASTM Standard D421-85, according to the United Soil Classification System (USCS). Further, the additions of fines changes the Atterberg Limits, and therefore the likelihood of obtaining an accurate soil classification is decreased.

3.1 Laboratory Investigation

This study was conducted in two phases—1) A determination of whether coffee grinder processing would break down sand-sized particles into fines and 2) A study of the influence of the coffee grinder processing on the Atterberg Limits of soil containing fines compared to standard mortar processing.

3.2 Phase 1: Does the coffee grinder break down larger soil particles into smaller particles?

In this phase, sand-sized particles were used. We began by 'processing' 40-60 (i.e., passes the Number 40, or 0.425 mm Sieve, but is retained on the Number 60, or 0.25 mm sieve) Ottawa Sand in a coffee grinder and comparing it to unprocessed sand from the same sample to discern whether the coffee grinder would produce fines. Dry sieve analyses (only) were performed for this phase. The Ottawa Sand samples were processed by using a soil splitter so that each control (no processing with a coffee grinder) was matched by a sample that was processed in a coffee grinder.

For the ground sample, we processed approximately 600 grams of sand using a new coffee grinder. The coffee grinder was only able to handle about 200 grams at a time. Each 200 gram portion was ground for 90 seconds while tilting the coffee grinder back and forth by hand (approximately 30°-45°from vertical in both directions). The RSAK instructions do not specify a 'processing time' related to the use of the coffee grinder; however, we selected 90 seconds in order to treat each specimen in a similar manner. After the three 200 g sub-samples were processed through a new coffee grinder (90 sec each) they were recombined into one sample. We used a 600 gram sample in order to optimize the accuracy of the grain-size-distribution determinations.

After the first 90 second processing of one 200 g sub-sample of Ottawa Sand, the grinder blades showed noticeable wear. Therefore we measured the grinder blade dimensions during the study. Two locations of the blade were measured: 1.) the width of the base of the blade closest to the center, and 2.) the length of the blade that forms an angle from horizontal (Fig. 1). The blades were measured before and after each time soil was processed until all 600 g were processed.

Data analysis included grain size distribution determinations in a standard dry sieve test for the Ottawa Sand processed in the grinder and the control sample of Ottawa Sand.

3.3 Phase 2 – Does coffee grinder processing change Atterberg Limits and soil classification?

For this phase of testing, two soils were utilized --a sample collected from beneath the Southeastern elevator in Fairchild Hall at the US Air Force Academy, given the name "Elevator Soil," which classifies as SP-SM, Poorly graded sand with silt, and a soil collected from Loveland, Colorado, given the name "Harte Clay" (collected by Lt Sean Harte in 2009 from Loveland, Colorado), which classifies as a CL, Sandy lean clay (containing 42% sand and less than 0.5% gravel).

Each set of soil samples (control and treated) was obtained for testing via a soil splitter. For the control, a mortar and pestle were used to break up clumps of soil into individual particles and the 'treated' soil was processed with the coffee grinder for 90 seconds as described above. Sieve analysis using the wet preparation method was used to test and classify the soils after their treatments with mortar and pestle (control) or with the coffee grinder.

The Harte Clay had been stored indoors for over two years, and was quite stiff--it was in hardened chunks. Hence, a rubber mallet was used to carefully break apart large chunks of the clay prior to any treatment. Three hundred grams of the soil (total) were used for the coffee grinder processing—and we used five 90 second cycles of processing approximately 60 g of soil. Measurements of the blades of the coffee grinder were taken before any soil was processed and after the five cycles of processing soils (as was done for the Ottawa Sand).

Experimental Results

4.1 Wear on Coffee Grinder Blades due to soil processing

The base width of new blades measured 10.1 mm, and the length of the new blade tips was 6.4 mm. The wear on the blade tip width (Figure 1, left side) was less than 1% of the original width for all measurements made. The length of the blades; however, had notable wear, depending on the soil processed, as shown in (Table 1).

The Elevator Soil wore down the blades much more quickly than the other soils tested. Figures 2 and 3 show the pictures that were taken after one processing cycle and three cycles, respectively, of Elevator Soil. The Harte Clay had very little effect on the wear of the blades. A total of five cycles of the Harte Clay were run through the grinder and the grinder had less wear on it than with only one cycle of Elevator Soil. The Ottawa Sand eroded the blades significantly, but not as much at the Elevator Soil.

Table 1- Measurements of coffee grinder blades after processing soil

Soil	**Number of 90 second cycles**	**% decrease in tip length**
Ottawa Sand	4	21
Elevator Soil	1	10
	2	28
	3	100 (no tip left)
Harte Clay	5	2

Figure 1: Top view of new RSAK coffee grinder, showing where blade dimensions were measured before and after processing soils.

Figure 2: The blades after one 90 second cycle of Elevator Soil

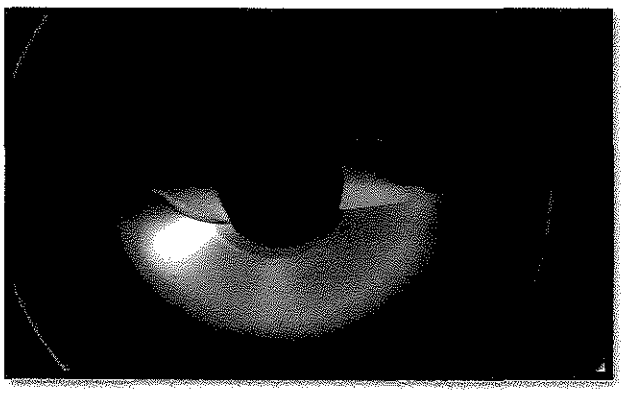

Figure 3: The blades after three 90 second cycles of Elevator Soil

4.2 Ottawa Sand Dry Sieve Analysis—Does coffee grinder processing produce fines?

The Ottawa Sand (control) was 99.8% sand with the remaining portion being fines (Fig 4). It was very well-sorted, the Coefficient of Uniformity (C_u) was 1.95 and the Coefficient of Curvature, (C_c) was 0.95. The soil classifies as SP, Poorly Graded Sand, according to the Unified Soil Classification System (USCS).

The first sample of Ottawa Sand that was processed with the coffee grinder resulted in 83.9% Sand with the remaining portion being fines (Fig. 4). The Coefficients of Uniformity and Curvature were not determined, since D_{10} was smaller than the opening size of the No. 200 Sieve (0.075 mm). Hence, the soil would either classify as SC or SM. Presumably the fines produced are non-plastic, and the soil would classify as SM. Three more samples of Ottawa Sand were processed with the coffee grinder, and the percentages of fines in each sample are shown in Figure 5, and indicate that the percentage of fines produced are relatively consistent, with values ranging from 15.9% to 18.5%.

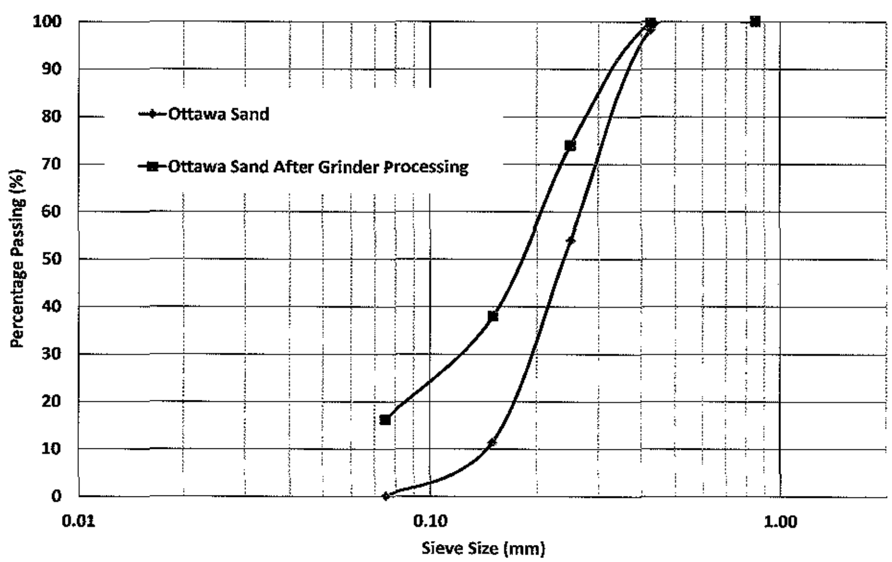

Figure 4: Grain size distribution of Ottawa Sand and Ottawa Sand after being processed in a coffee grinder for 90 seconds

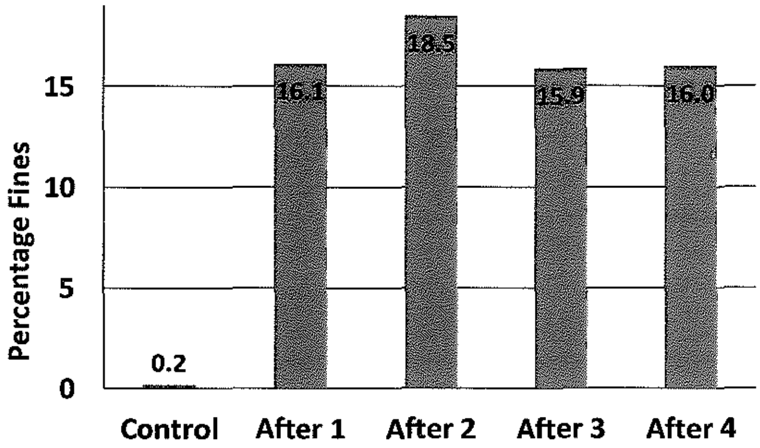

Figure 5: Percentage Ottawa sand passing the No. 200 Sieve for untreated soil (control) and after processing with the RSAK coffee grinder. After 1, means that this was first time that the coffee grinder was used, After 2 means that the coffee grinder had already processed one batch of soil (so that there was some wear on the blades); similarly for After 3 and After 4.

4.3 Influence of coffee grinder processing on grain size distribution, Atterberg Limits and soil classification of the Elevator Soil and Harte Clay

The grain size distributions for the control and treated samples of both the Elevator Soil and the Harte Clay are shown in Figures 6 and 7, respectively; and Figure 8 is a bar graph showing the percentage of fines for the control and processed specimens. The Elevator Soil contained 4% gravel, 87% sand and 9% fines. For coffee grinder processing, the same soil was found to contain no gravel, 72% sand and 29% fines—thus, the coarse grained soil content decreased by 19%, while the fines content increased by the same amount due to processing. For the Harte Clay, the fines increased from 57% to 64%. In each case, the coffee grinder processing resulted in the production of significant fines compared to the control specimen. For the Elevator Soil, the processing reduced the coarse material content to 77% of that of the original value and for the Harte Clay, the coarse particle content was reduced to 84% of the original value. The fines produced were enough to change the soil classification of the Elevator Soil from a dual-classification to that of Silty Sand (SM).

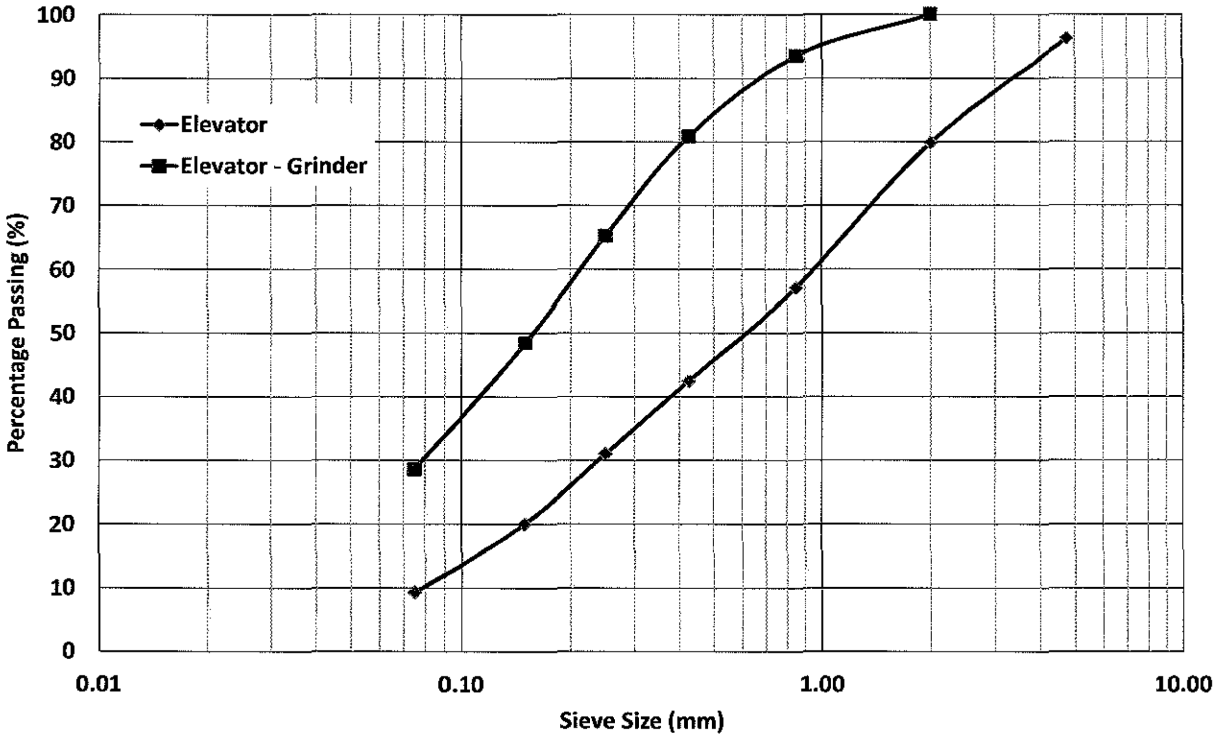

Figure 6: Grain Size Distributions for Elevator Soil and Elevator Soil processed with a coffee grinder.

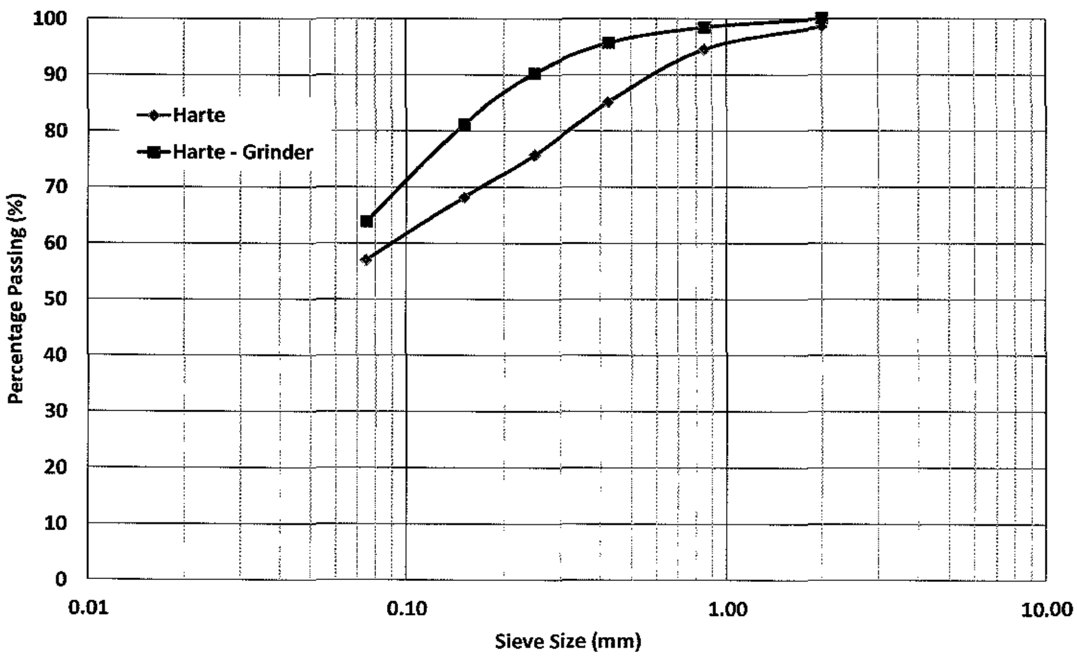

Figure 7: Grain Size Distributions for Harte Clay and Harte Clay processed with a coffee grinder.

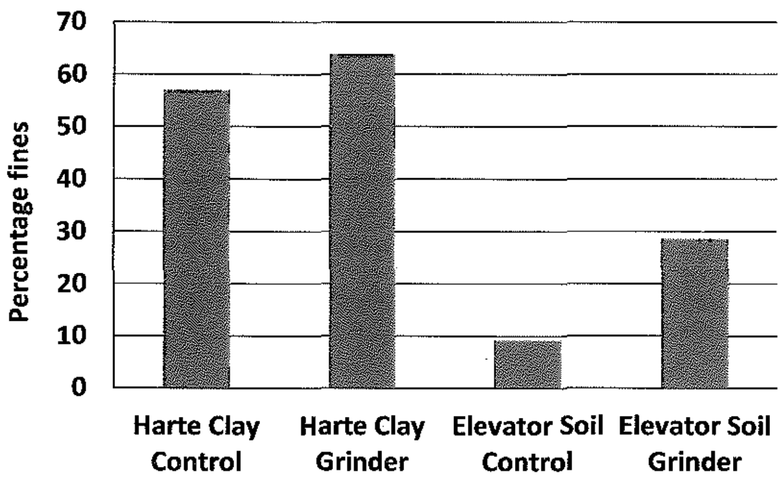

Figure 8: Percentage of the fines in the control and treated (after processing with the RSAK coffee grinder) samples of Harte Clay and Elevator Soil.

Table 2 lists the Atterberg Limits and the USCS classifications for matching control and coffee-grinder-processed specimens.

For the Elevator Soil, originally classified at SP-SM, the Liquid Limit could not be determined on the processed soil using the Casagrande procedure because the fines were non-plastic, and the Plastic Limit of the material passing the Number 40 sieve decreased slightly. The fines classify as ML for both the control and treated specimens.

Table 2: Influence of coffee grinder processing on the Atterberg Limits of Elevator Soil and Harte Clay

<table>
<tr><th>Soil</th><th colspan="2">Liquid Limit (%)</th><th colspan="2">Plastic Limit (%)</th><th colspan="2">Plasticity Index</th><th colspan="2">USCS</th></tr>
<tr><th></th><th>Control</th><th>Grinder</th><th>Control</th><th>Grinder</th><th>Control</th><th>Grinder</th><th>Control</th><th>Grinder</th></tr>
<tr><td>Ottawa Sand</td><td colspan="6">Not applicable to control, did not perform on grinder processed soil. Assumed that the fines would be non-plastic.</td><td>SP</td><td>SM</td></tr>
<tr><td>Elevator Soil</td><td>21</td><td>Non-plastic</td><td>19</td><td>17</td><td>2</td><td>Non-plastic</td><td>SP-SM</td><td>SM</td></tr>
<tr><td>Harte Clay</td><td>37</td><td>41</td><td>14</td><td>25</td><td>22</td><td>26</td><td>CL</td><td>CL</td></tr>
</table>

For the Harte Clay, both the Liquid Limit and the Plastic Limit increased due to processing the soil with the coffee grinder. The Liquid Limit increased from 36 to 41, and the Plastic Limit increased from 14 to 25. (Thus, the Plasticity Index decreased.) While the USCS classification of the soil did not change in this case, it suggests that for fine-grained soils that fall close to the A-line of the Plasticity Chart, the soil classification could change.

4. Discussion

The results of this research program support our hypothesis that the use of a coffee grinder to process soil changes the grain size distribution, and that the addition of fines can change the Atterberg Limits in at least some cases; both of which can result in a different soil classification. For the coarse Elevator Soil, originally an SP-SM, the fines production changed the soil classification to SM, while the Liquid Limit decreased from a measureable 21 to non-plastic, and Plastic Limit decreased from 19 to 17. For the Harte Clay (CL), the soil classification did not change; but the Liquid Limit and Plastic Limit both significantly increased. Therefore, for both the production of fines and the resulting impact on Atterberg Limits, the influence of using a coffee grinder to process soil cannot be quantified without further, systematic study.

A likely explanation for the Atterberg Limits to decrease for the Elevator Soil, is the addition of fines due to breaking of sand particles, which are non-plastic. The results align with those of Kayabali (2011). In the case of the Harte Clay, the coffee grinder may have broken not just sand particles, but clay particles, thus increasing surface area available to react with water.

Interestingly, the RSAK sometimes under-predicts the amount of fines in soils (Berney, et al, 2008).

> "…it is noted that, in all cohesive soil cases, the RSAK predicts a lower fine content as a direct result of not moistening the soil as per ASTM C117. ASTM C117 states that only when the accuracy of material passing the No. 200 sieve is required wash sieving should be used. The use of the coffee grinder is an attempt to mitigate this discrepancy, providing a means to generate sufficient fines quantity to differentiate fine-grained soils from coarse-grained soils.

Hence, the link between the use of the coffee grinder, which increases fines, and the small, dry sieve stack, which results in a under-prediction of fines might be an area of further study.

We emphasize that this limited research effort was intended to test the hypothesis described above, and it is not a critical investigation in regards to the validity of the RSAK. For example, although we processed each soil for 90 seconds in the coffee grinder, the RSAK does not specify an amount of time (Wahls 2008):

> To begin soil processing, the dried sample from the previous step is pulverized with a mortar and pestle and coffee grinder with care taken not to break up soft aggregate, but only soil clods that have formed during microwave drying.

It is very likely that in field use to process soils, the coffee grinder would be used for a shorter amount of time than 90 seconds, and would produce fewer fines than those produced in our study. In addition, the RSAK recommends the use of the coffee grinder to process clay soil, whereas we used it to process sands in order to test our hypothesis.

Finally, the wear on the blades of the coffee grinders due to soil processing indicates that for field use, the coffee grinder has a finite life span. It is logical to assume that the blades will continue to wear down until the coffee grinder can no longer break down the soil particles.

5. Conclusions

Based on the experiments conducted, we conclude that:

1. Using the processor with the Ottawa Sand establishes that the blades break down sand-sized particles into fines. The 90-second processing time resulted in the production of 15.9% to 18.5% of fines from the sand particles.
2. The amount of fines produced by 90 seconds of processing in a coffee grinder was enough to change the United Soil Classification System classification of and poorly-graded silt sand (SP-SM) to silty sand (SM).
3. The amount of fines produced by processing with a coffee grinder resulted in a reduction of coarse particles to 77% of the original value for the original SP-SM tested, and to 84% of the original value for the CL tested.
4. The Atterberg Limits determined for both treated soils—the Elevator Soil and the Harte Clay were different than those determined for the control specimens of each soil. They

decreased for the Elevator Soil and increased for the Harte Clay, suggesting that further study would be required to be able to adjust for the use of the grinder.

5. The coffee grinder blades wear down when processing soil. The degree of wear with each use varies depending on specific soil type, suggesting a limited lifespan for field use.

Acknowlegements

The authors wish to acknowledge the contributions of Lieutenants Kevin Doolittle and Eric Gilpatrick, who helped establish the experimental procedures described in this paper.

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